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Abstract Form

Modularity of 3D faces through Spectral Clustering

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Abstract. The facial morphology is the result of mazy interactions between environmental and epigenetic factors that lead to the composition of multiple subunits integrated to function as a whole. In this study, we combine modularity concepts from evolutionary developmental biology with unsupervised machine learning tools to provide a descriptive framework of the facial configuration of landmarks on a modular and thus local basis. We apply normalized spectral clustering to a database of 592 3D faces - represented with spatially dense meshes of 7,150 quasi-landmarks -, grouping vertices that are strongly correlated and connected to form compact modules. Given an average mesh configuration of the whole dataset, we first build the affinity matrix that encodes the similarity of each pair of landmarks. The affinity matrix assigns a high weight to strongly correlated landmark pairs while penalizing their inter-landmark geodesic distance measured on the average mesh configuration. The normalized Laplacian of the similarity matrix is then computed and its top-k eigenvectors (corresponding to the k smallest eigenvalues) are retained. The clustering is performed through the traditional k-means algorithm on the first eigenvectors of the Laplacian matrix, initializing the centers with a weighted probability distribution in order to account for variability due to seed selection. Since the strength of co-variation between the obtained modules is the criterion for evaluating integration and modularity in the input data, we recall the Escoufier coefficient from morphometric studies on biological shapes as a scalar measure of the co-variation between sets of landmarks. The statistical significance of the Escoufier coefficients among multiple sets of landmarks is established by means of a permutation test. The spectral clustering described in this work results in finding the correct patterns in a more robust and accurate way compared to other unsupervised clustering techniques such as k-means or k-means++, and the association values found on the first clusters show a good statistical significance.

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